ILC Positron Source Undulator

- Review of R&D progress to date
- Design options for improved performance

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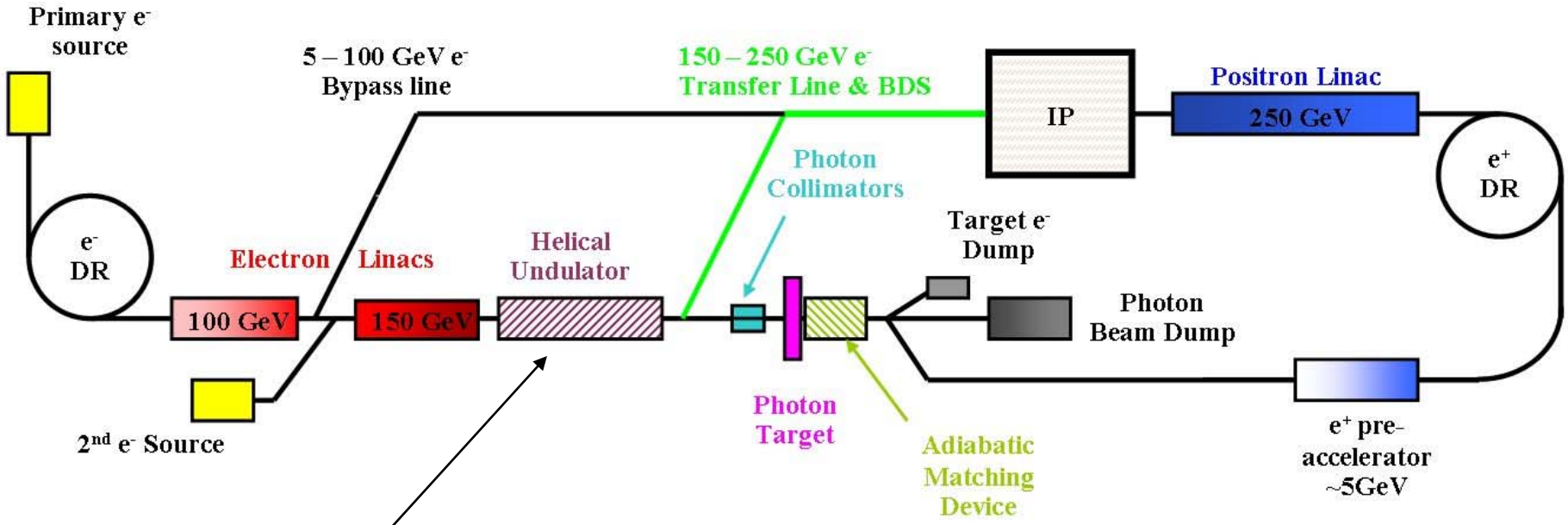
ILC Meeting, SLAC, 4/25/06

ILC Positron Source



Undulator parameters:

Parameter	Value	Units
Period	10	mm
Peak field	1.1	T
Type	Helical	-
Length	100-200	m
Max Photon Beam Power	95	kW

Undulator Development in the UK

Reference:

EUROTeV-heLiCal collaboration presentation by **Ian Bailey** (Cockcroft Institute & University of Liverpool), 12th January 2006;
http://www.lancs.ac.uk/cockcroft-institute/public/all_hands_workshop-january06/I_Bailey.ppt

- A short (30 cm) prototype has already been fabricated and tested
- Fabrication and test of a 3.5 m long prototype is planned for 2006-07

Short prototype design parameters:

Design field	0.8 T
Period	14 mm
Magnet bore	4 mm
Winding bore	6 mm
Winding section	4 × 4 mm^2
Overall current density	1000 A/mm^2
Peak field (not on-axis)	1.8 T

Long prototype design parameters:

Field on axis:	0.75 T
Period:	12 mm
Winding bore:	7 mm
Magnet bore:	6 mm

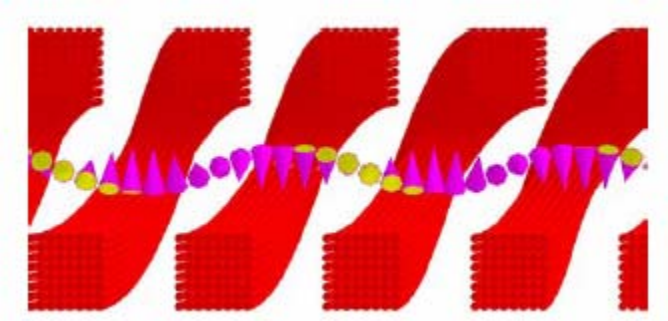
Target specification (John Sheppard):

Field on axis:	1 T
Period:	10 mm
Winding radius:	~6 mm

EUROTeV-heLiCal Prototype Design

References:

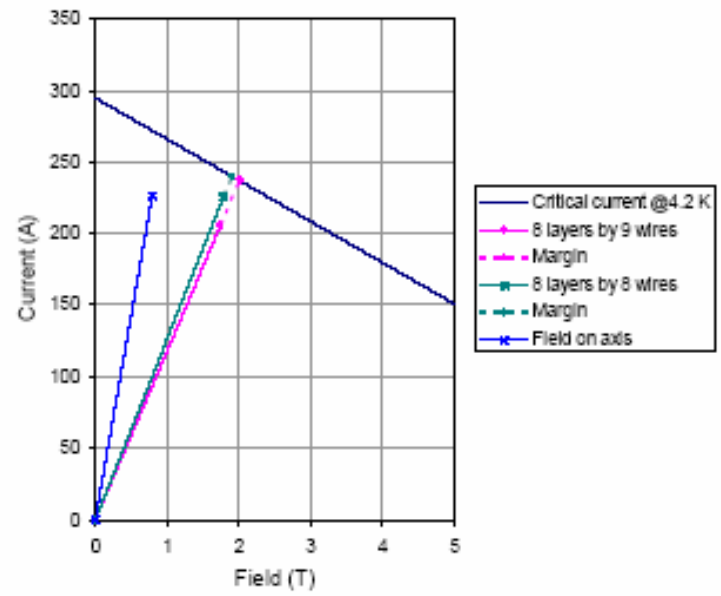
1. Y. Ivanyushenkov etal., Proceedings of PAC 2005
2. D. Scott et. Al, Proceedings of EPAC 2004



Design approach: Bifilar helix winding
(J. Madey, J. Appl. Phys. Vol 42 (1971)

Magnet features & parameters:

- Conductor: NbTi. 0.44 mm diam.
- Groove size: 4x4 mm
- Test: achieved 0.8 T on axis



ILC Undulator R&D Status

Progress to date:

- Undulator development by heLiCal collaboration is in advanced stage
- Sufficient performance and cost information for RDR should be available

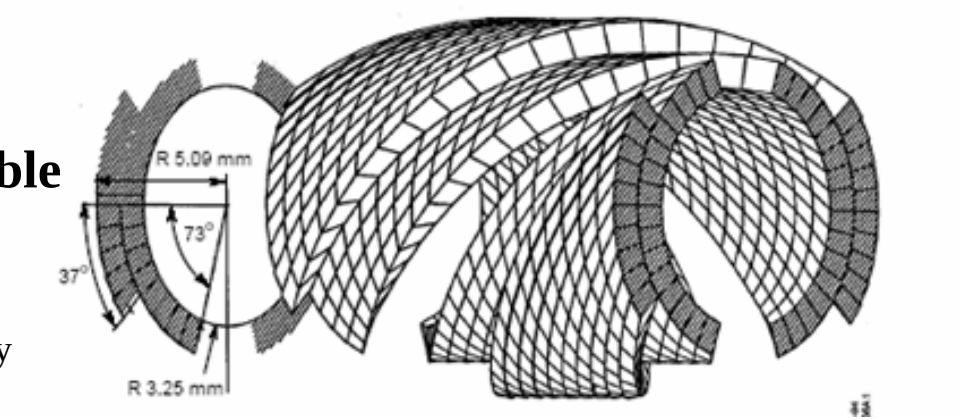
However, it appears that present parameters are below the optimal targets

Performance improvements may be obtained by:

- Better magnetic efficiency of the winding
  - *Coil and iron geometry optimization, higher packing factor*
- Improved conductor properties:
  - *NbTi: Artificial Pinning Centers (APC) conductor (available in rectangular geometry)*
  - *Nb_3Sn: operation at much higher Je demonstrated in undulator prototype with similar features*

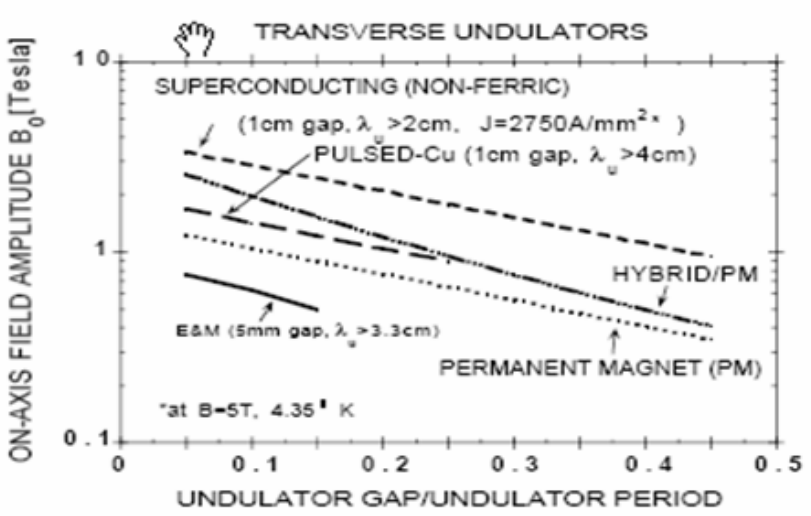
LBNL-SLAC Helical Undulator Design

- **Shell-type cross-section geometry**
- **Motivated by LCLS design studies**
- **Specialized optimization code available**

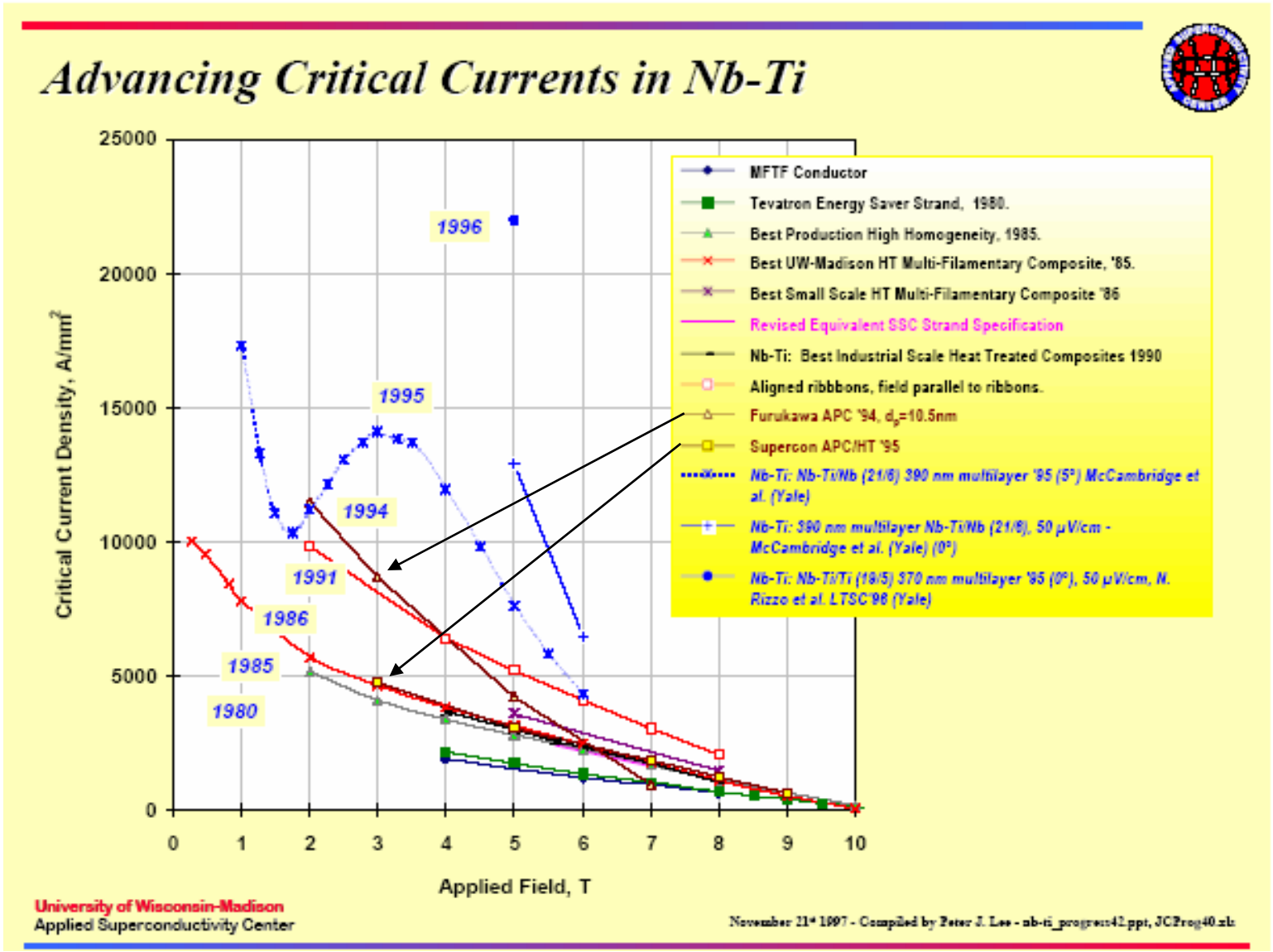


Publications:

- S. Caspi, "Magnetic Field Components in a Sinusoidally Varying Helical Wiggler. LBL-35928 July, 1994
- S. Caspi, "Stored Energy in a Helical Undulator", LBL SC-MAG-474, 1994.
- S. Caspi, "Magnetic Field Components in a Helical Dipole Wiggler with Thick Windings", LBL, 1994
- S. Caspi, "A Superconducting Helical Undulator for Short Wavelength FELs", LBL Report SC-MAG-475, 1994.
- S. Caspi, R. Schlueter, R. Tatchyn, "High Field Strong Focusing Undulator Designs for X-ray Linac Coherent Light Source (LCLS) Applications". SLAC-Pub 95-6885. PAC 1995.
- S. Caspi and C. Taylor , “An experimental superconducting helical undulator”, NIMA Volume 375, 1996
- R. Tatchyn, et al, “R&D toward a linac coherent light source (LCLS) at SLAC”, NIMA, Vol. 375, 1996.



NbTi with Artificial Pinning (APC)



LBNL Nb_3Sn Undulator R&D

Collaboration of AFRD & Engineering Div.

Considered for ALS applications:

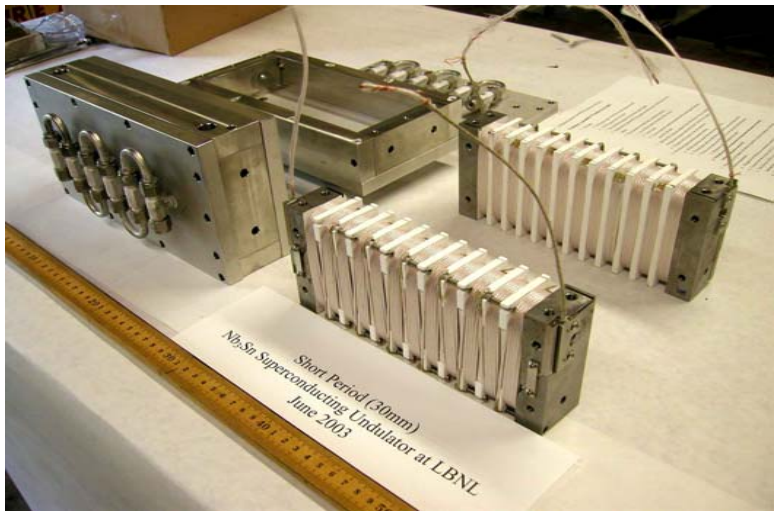
- Radiator for femto-slicing experiment
- Source for protein crystallography

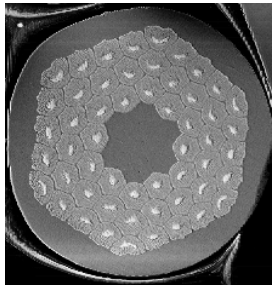
LDRD results (2003-04):

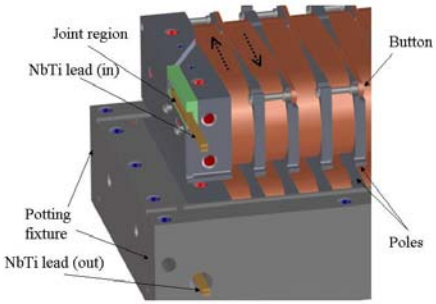
- Two prototypes using 6-strand cable
- 30mm period prototype; 80% of Jc
- 14.5mm period prototype: ~75% Jc

WFO (2005-06, for Argonne Nat. Lab):

- Test single strand conductor
- Design and fabrication improvements
- Reached short sample Jc in 4 quenches



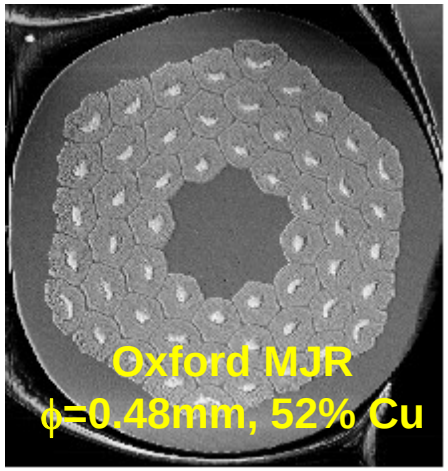




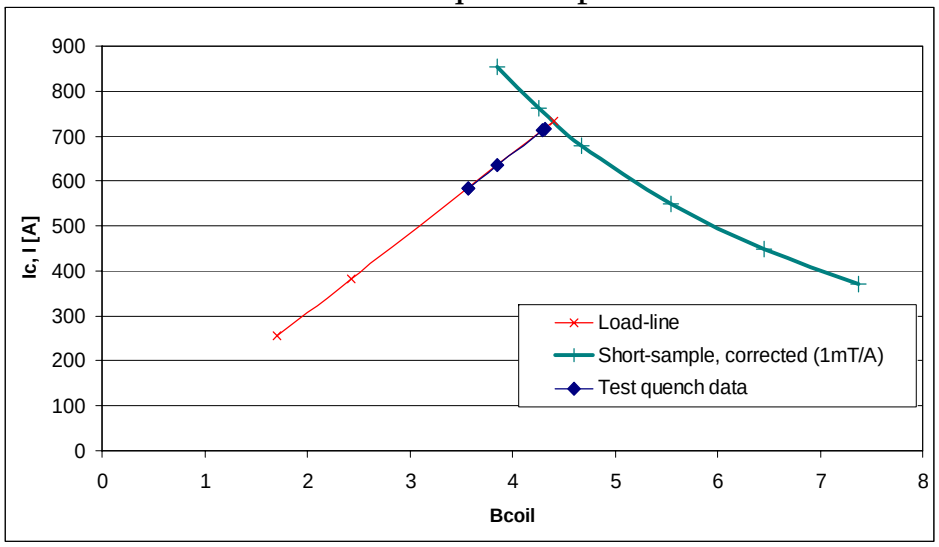
Prototype III Undulator

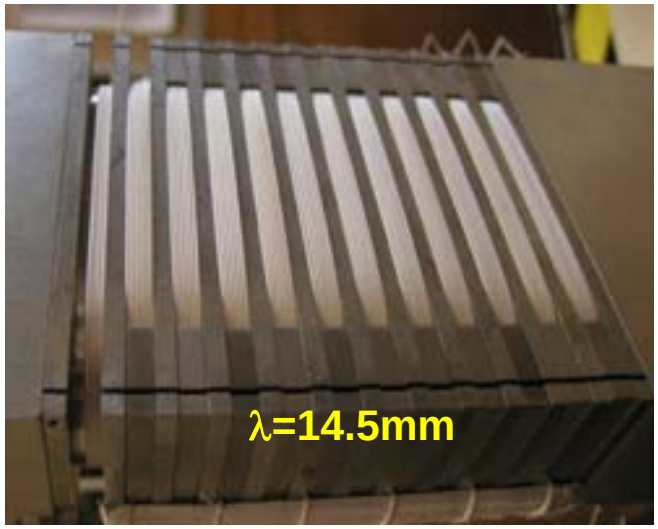
•Five quenches:

- ➢585A, 585A, 635A, 717A, 714A
- ➢At 717A:
  - J_{sc}=8250A/mm2
  - J_{cu}(quench)=7600A (self-protected)
  - J_{av}=1760A/mm2 (using full pocket size)



Load lines and quench performance



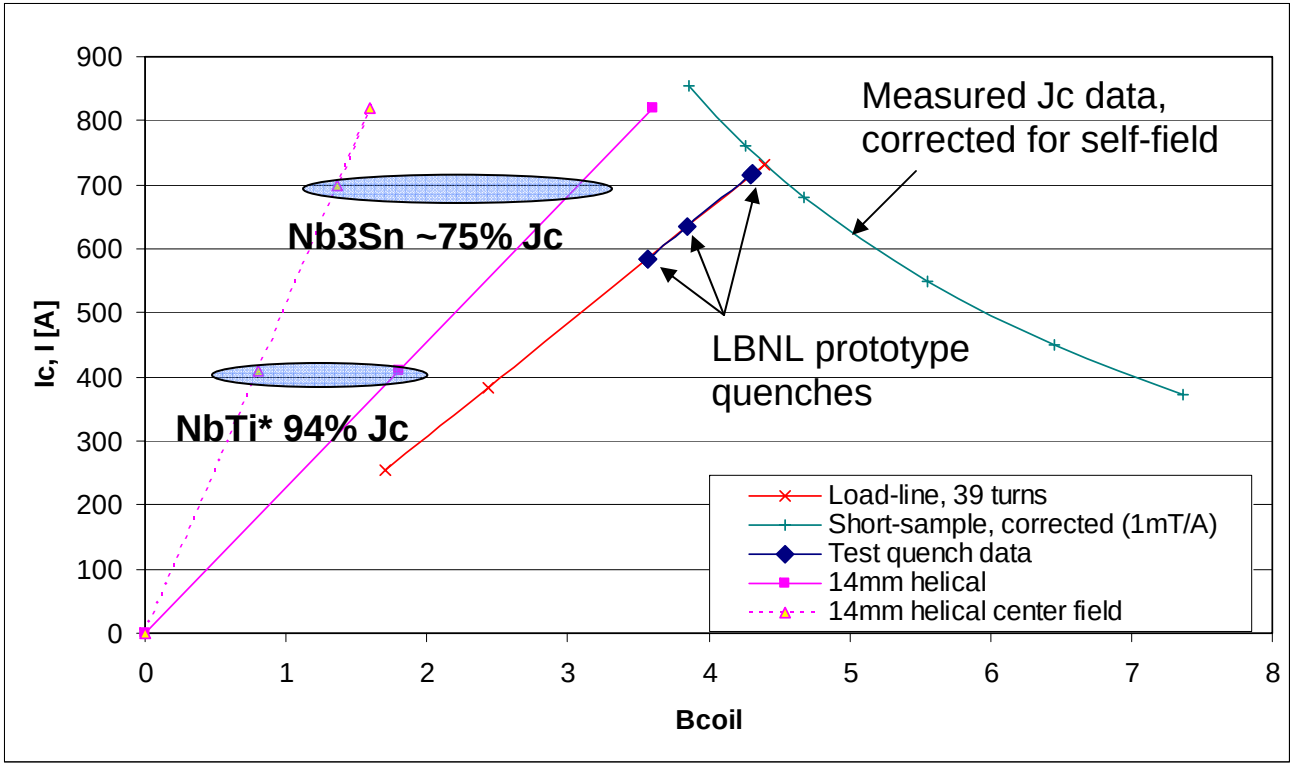


Relevance to ILC Design

- Use same load-line data, apply same Nb3Sn conductor as LBNL prototype
  - Cross section close match (~4x4mm^2 vs 15.90mm^2 for LBNL prototype)
  - Assume 39 turns of ϕ=0.48mm
- Reasonable operating point at 700A => 3.07 T on coil, 1.37 T on-axis, K=1.78
- This performance can be used to reduce period to yield 20MeV photons

1.4 T

0.8 T



*1000A/mm2 J_{av} converted to current for comparison; actual conductor operated at 226A)

Nb3Sn Undulator Publications

Papers:

- Prestemon, S. et al. “Design and evaluation of a short period Nb3Sn superconducting undulator prototype”, Presented at PAC2003, Portland, Oregon, May 2003. Proceedings, PAC2003
- M. A. Green, D. R. Dietderich, S. Marks, S. O. Prestemon, “Design Issues for Cryogenic Cooling of Short Period Superconducting Undulators”, presented at CEC-ICMC, Anchorage, Alaska, Sept. 22-26, 2003. Advances in Cryogenic Engineering, AIP, Vol. 49, p 783-790.
- Prestemon, S.; Dietderich, D.;Marks, S.;Schlueter, R. , “NbTi and Nb3Sn superconducting undulator designs”, presented at SRI 2003, San Francisco, Aug. 2003. Synchrotron Radiation Instrumentation, AIP, vol. 705, p 294, 2004.
- Ross Schlueter, Steve Marks, Soren Prestemon, and Daniel Dietderich, “Superconducting Undulator Research at LBNL”, Synchrotron Radiation News, January/February 2004, Vol. 17, No. 1.
- S. O. Prestemon, D. R. Dietderich, S. E. Bartlett, M. Coleman, S. A. Gourlay, A. F. Lietzke, S. Marks, S. Mattafirri, R. M. Scanlan, R. D. Schlueter, B. Wahrer, B. Wang, “Design, Fabrication and Test Results of Undulators Using Nb3Sn Superconductor”, IEEE Transactions on Applied Superconductivity, June 2005 (Presented at ASC 2004, Jacksonville, Fl.)
- S. Prestemon, R. Schlueter, S. Marks, D. Dietderich, “Superconducting Undulators with Variable Polarization and Enhanced Spectral Range”, presented at MT19, Sep. 18-23, 2005, Genoa, Italy

Presentations:

- K. Robinson, “Superconducting Undulator R&D Collaboration Program in the United States”, Workshop on Superconducting Undulators & Wigglers, Grenoble, France, 1 July, 2003. http://www.esrf.fr/NewsAndEvents/Events/Workshop30-06-03/
- S. Prestemon, D. Dietderich, S. Gourlay, P. Heimann, S. Marks, G. L. Sabbi, R. Scanlan, R. Schlueter “Superconducting R&D at LBNL”, Workshop on Superconducting Undulators & Wigglers, Grenoble, France, 1 July, 2003. http://www.esrf.fr/NewsAndEvents/Events/Workshop30-06-03/
- S. Prestemon, D. Dietderich, S. Marks, R. Schlueter, “Nb3Sn Superconducting Undulator Designs: performance Issues and Design Concepts”, Workshop on Undulator systems for X-FELs (WUS2005), June 6-8, 2005 DESY Hamburg, Germany

Proposed Development Plan

FY06: Performance requirements & specs (0.1 FTE)

- Comparison of design options, parameter space
- Contributions to preliminary cost estimates

FY07: Undulator studies & design of a proof-of-principle prototype (0.5 FTE)

- Conductor options evaluation and selection; conceptual design
- Design of a simple prototype to validate the design choices
- Impact of heat loads and vacuum issues

FY08: Technology demonstration (2 FTE, 100k$ M&S)

- Fabrication and testing of a proof-of-principle prototype
- Start the design of a fully engineered prototype
- Refined cost estimates

FY09: Full design validation (3 FTE, 300k$ M&S)

- Fabrication and testing of a fully engineered prototype